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Memorandum

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to Christopher Diaz, City Attorney, City of Milpitas
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from Jeff Caton, ESA Project Manager

cc Peter Deibler, HF&H Consultants

subject Results of Assessing Air Quality and Greenhouse Gas Emissions Impact of Solid Waste Diversion Scenarios

Summary of Results

As the analysis presented herein demonstrates, criteria air pollutants and greenhouse gas (GHG) emissions associated with the worst case scenario for the collection and processing of recyclables and organics (diversion project) fall well below the thresholds of significance issued by the Bay Area Air Quality Management District (BAAQMD) and the San Joaquin Valley Air Pollution Control District (SJVAPCD). Even when considering the emissions impact associated with the worst case scenario for the City-approved waste disposal contract (disposal project) in conjunction with the diversion project, the total emissions still fall well below the BAAQMD and SJVAPCD thresholds. With respect to GHG emissions, recycling and composting provide lifecycle benefits that far outweigh the impacts from transporting and processing of both the landfilled materials and the materials diverted from landfill.

As supported by this analysis, the City of Milpitas' new and proposed contractual arrangements for hauling, landfill disposal, and diversion of solid waste materials (the combined disposal and diversion projects considered herein) are exempt from CEQA per CEQA Guidelines section 15301, as the contracted activities represent the continued operation of existing public facilities that involve "negligible or no expansion of use beyond that existing at the time of the lead agency's determination."

Background

The City of Milpitas (City) is conducting a solid waste collection, hauling, and disposal procurement process that includes separate contracts for landfill disposal and for diversion of recyclables and organics from landfill. The City awarded the solid waste disposal contract in March 2016. The City has also received six proposals to provide collection, hauling, processing, and recovery services for solid waste, recyclables and organics, with the intent to ensure compliance with State requirements for increasing solid waste diversion from landfill and reducing landfill emissions over time. This analysis considers the "worst-case" scenario for air quality and greenhouse gas (GHG) impacts represented by the four shortlisted diversion proposals, as compared to the baseline condition where Republic Services collects and transports recyclables and green waste to their nearby Newby Island Resource Recovery Park in San Jose for processing, in order to determine whether air quality and net GHG impacts exceed identified significance thresholds. Compared to baseline, any of the four shortlisted proposals would increase diversion of solid waste from landfill, and thus reduce the GHG emissions (i.e. methane) associated with landfilled organic material.

Method of Analysis

ESA analyzed the air quality and GHG impacts represented by the worst-case scenario (most loads and longest distances), for collecting and processing materials diverted from landfill disposal, including single-stream recyclables, green waste, food waste, and construction and demolition (C&D) waste. HF&H Consultants provided information based on data submitted by the proposers regarding the types of trucks used to transport materials; the maximum expected annual tonnages (based on cart, bin and debris box collection data for recyclables and organics); and the longest transport distances proposed for each stream. For the baseline situation, all materials (solid waste, recyclables, organics, and C&D waste) are assumed to be transported 3.7 miles to the Newby Island facility in San Jose, the one way distance from the City center (defined as the Milpitas City Hall) to the Newby Island Landfill. For the shortlisted proposals, the furthest destinations for each stream include:

- ACI's Aladdin Street Material Recovery Facility (MRF) in San Leandro for recyclables (26.7 miles);
- Republic Service's Newby Island in San Jose, with subsequent transfer to Forward Landfill in Stockton for organics (81.6 miles);
- City of Sunnyvale's SMaRT station for C&D waste (7.3 miles).

Table 1 provides a summary of the data used in our analysis. The worst case scenario is analyzed for two vehicle fueling alternatives: compressed natural gas (CNG) and biodiesel B20 (20% biodiesel).

Table 1: Transport & Waste Diversion Data	**Scenario**		**Baseline**
	Fuel Option 1	**Fuel Option 2**	
TRANSPORTATION: Collection and Hauling			
Collection Vehicle Data			
Model year	T7 SWCV	T7 SWCV	T7 SWCV
Model year	2017	2017	2016
Fuel	CNG	Biodiesel B20	CNG
Speed	30	30	30
Materials Collection Data			
Annual Recycling Tons collected	20,339	20,339	10,932
Distance - CIty center to recycling facility (ACI) - miles	26.7	26.7	3.7
Annual Yard Trimmings Tons Collected	7,419	7,419	5,466
Annual Food Waste Tons Collected	5,199	5,199	244
Distance - City center to Newby; transfer to Forward - miles	81.6	81.6	3.7
Annual C&D Tons Collected *	14,593	14,593	7,190
Distance - City center to C&D recycling facility (SMaRT) - miles	7.3	7.3	3.7
Annual Direct Haul Loads	8,119	8,119	4,940
Annual Direct Haul Transport Hours	9,260	9,260	1,411
Annual Direct Haul Transport Mileage (VMT)	277,795	277,795	42,328

** The City currently has a non-exclusive debris box system for C&D materials, with approximately twelve companies including the City's exclusive franchise contactor for solid waste, recyclables and organics collection. Thus, the baseline tonnage includes only C&D materials currently collected by the current collection franchisee through its nonexclusive debris box contract since other contractors take materials to a variety of facilities. However, the City is considering making the C&D debris box service part of the exclusive agreement, and this as represented by the higher tonnage figure shown for the two scenarios representing the total nonexclusive system tons.*

To estimate the transportation-related air quality and GHG emissions for routing the materials to each facility, ESA used emission factors developed for a separate study[1] of solid waste transport and disposal, based on the current version of California Air Resources Board (CARB) EMission FACtor model (EMFAC2014) and supporting documentation. Criteria air pollutants[2] were estimated by multiplying vehicle miles traveled (VMT) by the emission factors for each fuel (grams/VMT); GHG emissions were estimated by converting VMT to units of fuel used for the truck type, and multiplying fuel use by emission factors for metric tons carbon dioxide equivalent (MT CO2e) per unit of fuel consumed.

ESA also analyzed the lifecycle GHG emissions benefits of composting and recycling, based primarily on Compost Emission Reduction Factors (CERFs) and Recycling Emission Reduction Factors (RERFs) developed by the CARB to support GHG quantification by public agencies applying for Greenhouse Gas Reduction Fund (GGRF) appropriations per Senate Bill 862 (Senate budget and Fiscal Review Committee, Chapter 36, statutes of 2014). CERFs and RERFs measure the GHG emission reduction benefits of the composting and recycling processes, respectively, including the use of their end-products, as compared to a baseline scenario of landfill disposal with landfill gas capture. For composting, the GHG benefits result from avoided methane emissions from landfilling, reduced soil erosion, and a decrease in fertilizer and herbicide use. For recycling, the GHG benefits result from the energy savings associated with material reuse and manufacturing with recycled content (i.e., recovered fiber, plastic, and glass). CERFs and RERFs also account for the transportation emissions associated with processing, after receiving materials at the material recovery facility (MRF).

Results

The transportation-related air quality and GHG impacts of the worst case scenario (with two transportation fuel options), summarized below in **Table 2**, were assessed and compared to the impact associated with the City's current baseline of collecting and direct hauling diverted materials to the Newby Island facility in San Jose. In summary, both fuel options for the worst case scenario increase criteria air pollutants and GHG emissions from transportation, relative to current practice. GHG estimates are provided for both tailpipe emissions (combustion of fuel) and lifecycle emissions (combustion plus emissions associated with extraction, processing and delivery of fuels to fueling stations).

Table 2: Waste Diversion Transportation Emissions	**Scenario**		**Baseline**	**Worst Case Net Emissions**
	Fuel Option 1	**Fuel Option 2**		
Criteria Pollutants - Tailpipe Emissions - short tons per year (tpy)				
ROG	0.01335	0.00958	0.00203	0.01131
NOx	0.19898	0.07833	0.03032	0.16866
PM-10	0.00031	0.00078	0.00005	0.00073
PM-2.5	0.00031	0.00074	0.00005	0.00070
Greenhouse gases - Tailpipe Emissions - metric tons per year				
CO2e	474.5	458.3	72.3	402.2
Greenhouse gases - Lifecycle Emissions - metric tons per year				
CO2e	602.2	435.9	91.8	510.4

[1] ESA Memo to City of Milpitas: Results of Assessing Air Quality and Green House Gas Emissions Impact of Solid Waste Transport Scenarios. March, 2016.

[2] Criteria air pollutants include ROG: Reactive Organic Gases; NOx: Oxides of Nitrogen; PM10: Particulate Matter less than 10 microns diameter; PM2.5: Particulate Matter less than 2.5 microns diameter.

As described previously, the GHG emissions benefits of recycling and organics diversion are based on CERFs and RERFs developed by CARB, developed for the common subcategories of recoverable organics and recyclables.[3] ESA derived diversion tonnages for recyclable and organic material substreams based on the 2008 StopWaste Alameda County Waste Characterization study, the results of which are summarized in **Table 3**, showing results for City of Fremont (a City located adjacent to Milpitas) and for the County as a whole. The StopWaste study indicates that the City of Fremont solid waste contained approximately 47% organics (excluding lumber) and 17% recyclable materials (including lumber) in 2008.

Table 3: Materials Composition base on 2008 Alameda County Waste Characterization Study

	City of Fremont	Alameda County
Recyclable Glass	1.0%	1.7%
HDPE	0.3%	0.3%
PET	0.4%	0.4%
Corrugated cardboard	4.2%	3.1%
Office Paper (high grade paper)	1.3%	1.2%
Magazines/3rd class mail (mixed paper)	3.9%	4.5%
Newspaper/telephone books	0.8%	0.8%
Dimensional lumber (untreated lumber + palettes)	4.6%	5.1%
Aliuminum cans	0.1%	0.2%
Steel cans	0.5%	0.5%
TOTAL RECYCLABLES	17.1%	17.8%
Other glass	3.0%	1.3%
Other paper	1.9%	1.3%
Other plastics, films	9.5%	9.2%
Other metals	3.6%	3.6%
Inerts	11.8%	11.4%
HHW	0.9%	1.0%
Special Waste	4.6%	3.5%
TOTAL OTHER	35.3%	31.3%
Food Waste	15.4%	18.7%
Yard Trimmings & Greenwaste ADC	5.9%	5.7%
Compostable paper	9.2%	10.1%
Other Organics (excluding lumber)	16.9%	16.5%
TOTAL ORGANICS	47.4%	51.0%

Table 4 summarizes how the City of Fremont waste characterization percentages translate to annual recovered tons of recyclables for the City of Milpitas, based on the collection tonnages being proposed. Table 4 also shows what recovery of the recycled materials means in terms of GHG emissions benefits, based on the RERFs. Note that the estimates in Table 4 assume a two-thirds recovery rate for all materials received at the recovery facility.

[3] For recyclable aluminum and steel cans, ESA used emission factors from EPA's Waste Reduction Model (WARM); RERFs were not developed for these materials due to the fact that recycling of these materials is market-driven and already well established and thus considered outside the bounds of California's Cap and Trade system for GHG emissions.

Table 4 - Recycling GHG Benefits		**Scenario**		**Baseline**
		Fuel Option 1	**Fuel Option 2**	
Recycling factors and tonnages				
Recyclables recovery rate assumption (for all materials):	0.667			
	RERF MTCO2e/ ton	Annual Recovered Tons		
Glass	0.18	136	136	73
HDPE	0.85	41	41	22
PET	1.54	54	54	29
Corrugated cardboard	5.12	569	569	306
Office Paper (high grade paper)	4.32	176	176	95
Magazines/3rd class mail (mixed paper)	0.40	529	529	284
Newspaper/telephone books	2.75	108	108	58
Dimensional lumber (untreated lumber + palettes)	0.21	624	624	335
Aluminum cans (WARM)	9.11	14	14	7
Steel cans (WARM)	1.81	68	68	36
Greenhouse gas reduction benefit				
		Annual GHG benefit (MT CO2e)		
Glass		24	24	13
HDPE		34	34	4
PET		84	84	5
Corrugated cardboard		2,913	2,913	54
Office Paper (high grade paper)		761	761	17
Magazines/3rd class mail (mixed paper)		213	213	50
Newspaper/telephone books		298	298	10
Dimensional lumber (untreated lumber + palettes)		131	131	59
Aluminum cans		124	124	66
Steel cans		123	123	66
Annual MT CO2e reduction		4,704	4,704	344

Table 5 summarizes how the waste characterization percentages translate to annual recovered tons of organics for the City of Milpitas, based on the collection tonnages being proposed. Table 5 also shows what recovery of organics means in terms of GHG emissions benefits, based on the CERFs.

Table 5 - Organics Diversion GHG Benefits	**Scenario**		**Baseline**
	Fuel Option 1	**Fuel Option 2**	
Organics factors and tonnages			
Annual Yard Trimmings Tons Collected	7,419	7,419	5,466
CERF (MT CO2e/short ton)	0.18	0.18	0.18
MT CO2e	1,305	1,305	962
Annual Food Waste Tons Collected	5,199	5,199	244
CERF (MT CO2e/short ton)	0.36	0.36	0.36
MT CO2e	1,850	1,850	87
Annual compostable paper collected	1,871	1,871	1,006
CERF (MT CO2e/short ton) - assume same as yard trimmings (conservative	0.18	0.18	0.18
MT CO2e	329	329	177
Greenhouse gas reduction benefit			
Annual MT CO2e reduction	3,155	3,155	1,048

Table 6 presents a summary of the GHG emissions associated with the Milpitas waste diversion worst case scenario. Accounting for the benefits of recovering organics and recyclables from the waste stream, both fueling options for the worst case scenario demonstrate a marked improvement in GHG emissions over the baseline situation. Including the lifecycle emissions associated with transportation fuel usage, the net annual GHG emissions benefit ranges from 5,956 to 6,123 MT CO2e. Notes on the assumptions, methods, and emissions factors used in the analysis are summarized below Table 6. Additional notes regarding the transportation analysis are included as *Attachment A: GHG/AQ Modeling Assumptions and Methodology*.

Table 6 - Summary of GHG Emissions Benefits of Milpitas Waste Diversion Scenarios

		Scenario		Baseline
		Fuel Option 1	Fuel Option 2	
COLLECTION and HAULING				
Tailpipe GHGs	MT CO2e	474.5	458.3	72.3
Lifecycle GHGs	MT CO2e	602.2	435.9	91.8
ORGANICS (includes lifecycle transportation)				
	Annual MT CO2e	-3,155	-3,155	-1,048
RECYCLING (includes lifecycle transportation)				
	Annual MT CO2e	-4,704	-4,704	-344
Net Annual Lifecycle GHG emissions (MT CO2e)		**-7,257**	**-7,423**	**-1,301**
Comparison to Baseline - Net Annual Lifecycle GHG emissions (MT CO2e)		**-5,956**	**-6,123**	

Notes and Key Assumptions
Used same emission factors for vehicle emissions as in Waste Transport analysis
Baseline diversion data based on information in RFP; assumes 50% of industrial rolloff loads (recycling and solid waste) is C&D recycling
To estimate diversion tonnages, used 2008 StopWaste Alameda County Waste Characterization data for City of Fremont (close proximity fo Milpitas) - Countywide data is similar
Recyclables recovery rate = 66.7%
For recycling (other than metals), used Recycling Emission Reduction Factors (CERFs) from CARB 2016
For metals recycling used WARM emission factors
For organics, used Compost Emission Reduction Factors (CERFs) from CARB 2016
For composting, used CERFs for Aerated Static Pile (ASP) method
CERF for compostable paper assumed to be same as for yard trimming (conservative)
Diverted dimensional lumber includes untreated lumber + palettes
Residues are not considered in the analysis

Impact Conclusions

As shown in **Tables 7 and 8**, the criteria air emissions and GHG emissions associated with the worst case scenario for the collection and processing of materials diverted from landfill disposal (diversion project worst case) fall well below the thresholds of significance issued by the Bay Area Air Quality Management District (BAAQMD) and the San Joaquin Valley Air Pollution Control District (SJVAPCD)[4]. Further, if the emissions impact associated with the worst case scenario for waste disposal hauling (disposal project worst case) is considered in conjunction with the diversion project worst case, the total net emissions compared to baseline still fall well

[4] These are the two Air Districts having jurisdiction over the facilities being considered in the procurement process

below the thresholds.[5] With respect to GHG emissions, recycling and composting provide lifecycle benefits that far outweigh the impacts from transporting and processing the diverted materials.

Table 7: Comparison to Thresholds of Significance - Criteria Air Pollutants

Compound	BAAQMD Threshold (tpy = short tons per year)	SJVAPCD Threshold (tpy)	Diversion Project Worst Case (tpy)	Disposal Project Worst Case (tpy)	Total Project Worst Case (tpy)	Exceed threshold?
ROG	10	10	0.01131	0.02562	0.03694	No
NOx	10	10	0.16866	0.62555	0.79421	No
PM-10	15	15	0.00073	0.00201	0.00273	No
PM-2.5	10	15	0.00070	0.00192	0.00261	No

Table 8: Comparison to Thresholds of Significance - GHG Emissions

Compound	BAAQMD Threshold	SJVAPCD Threshold	Diversion Project Worst Case	Disposal Project Worst Case	Total Project Worst Case	Exceed threshold?
CO2e (metric tons per year)	1,100	NA	-5,956	987	-4,969	No

[5] In addition, the baselines for the cumulative impacts of both the disposal analysis and the diversion analysis understate the true baseline because both exclude the impacts of the current nonexclusive debris box system from the baseline, and as noted earlier the diversion analysis, assumes C&D processing provided exclusively through the franchise.

Sources

CARB, 2011, *Method for Estimating Greenhouse Gas Emission Reductions From Compost from Commercial Organic Waste*, November 2011. Available at: http://www.arb.ca.gov/homepage.htm

CARB, 2016a, *Method for Estimating Greenhouse Gas Emission Reductions from Diversion of Organic Waste from Landfills to Compost Facilities*, March 2016. Available at: http://www.arb.ca.gov/cc/capandtrade/auctionproceeds/quantification.htm

CARB, 2016b, *Greenhouse Gas Quantification Methodology for the California Department of Resources Recycling and Recovery Waste Diversion Grant and Loan Program*, June 10, 2016. Available at: http://www.arb.ca.gov/cc/capandtrade/auctionproceeds/quantification.htm

CARB, 2016c, *Greenhouse Gas Reduction Calculator for FY15-16, Waste Diversion Grant and Load Program, Greenhouse Gas Reduction Fund*. Available at: http://www.arb.ca.gov/cc/capandtrade/auctionproceeds/quantification.htm

US EPA Waste Reduction Model (WARM) - version 13: https://www3.epa.gov/epawaste/conserve/tools/warm/Warm_Form.html

US EPA, 2015, Documentation for Greenhouse Gas Emission and Energy Factors Used in the Waste Reduction Model (WARM), March 2015

Attachment A: GHG/AQ Modeling Assumptions and Methodology

ESA used a variety of models and quantification to estimate GHG and criteria air pollutant emissions associated with transportation, including the EMFAC2014. Table A-1 lists general assumptions used for calculating route mileage, waste tonnages, hauling times and hauling speeds.

Table A-1: General Assumptions for Transportation Analysis	
1	Direct haul assumes round-trip from city center to facility for all loads except last load of the day (or last partial load of the day) which assumes the vehicle travels to the haulers' corporate yards
2	Approximate City center location at 455 E. Calaveras Blvd.
3	Material tonnages, number of loads per week, average tons per route vehicle, transport hours, and other route assumptions are based on proposal information; actual operating conditions will vary. This data is used to calculate VMT and travel hours.
4	The analysis focuses on material tonnage estimates provided by the proposers. Alternative proposals will result in less solid waste tonnage.
5	Average hauling times for collection vehicles were based on average speed of 30 mph.
6	Population growth, which may be large, is not factored into analysis.

Table A-2 summarizes the emission factors used in the analysis, while Table A-3 lists assumptions and data sources used for emission factors and fuel efficiency. For modeling tailpipe criteria air pollutants (ROG, NOx, PM10 and PM2.5) from diesel and biodiesel, ESA used the California Air Resources Board (CARB) EMission FACtor model (EMFAC2014) to derive emission factors on a grams per mile basis, using average route speeds and selecting the T7 Solid Waste Collection Vehicle (SWCV) for collection hauling, and T7 Tractor vehicle category for the long haul transfer of MSW in the two GWR scenarios. For CNG, emissions factors for criteria air pollutants are based on a CARB study of CNG urban buses, as presented in EMFAC2014 Technical Documentation.

TABLE A-2 – Transportation Emissions Factors Used in Analysis of Criteria Air Pollutants and GHG Emissions

Fuel	EMFAC Vehicle Category	Calendar Year	Model Year	Speed	Criteria Pollutants – Tailpipe Emissions (g/mile)				Greenhouse Gases						Heat content of Fuel (LHV)	Truck Fuel Efficiency
					ROG	NOx	PM-10	PM-2.5	Lifecycle Emissions	Tailpipe Emissions	Lifecycle Emissions	Tailpipe Emissions	Lifecycle Emissions	Tailpipe Emissions		
Diesel (CA ULSD)					g/mile				g of CO2e/MJ		MT CO2e/MMBtu		MT of CO2e/gallon		Btu/gallon	mpg
	T7 SWCV	2017	2012	30	0.0518	0.2826	0.0037	0.0035	102.01	74.85	0.108	0.079	0.014	0.010	128,488	4.9
	T7 SWCV	2017	2012	40	0.0281	0.1840	0.0032	0.0031	102.01	74.85	0.108	0.079	0.014	0.010	128,488	4.9
	T7 SWCV	2017	2015	30	0.0391	0.2559	0.0028	0.0027	102.01	74.85	0.108	0.079	0.014	0.010	128,488	4.9
	T7 SWCV	2017	2015	40	0.0212	0.1666	0.0024	0.0023	102.01	74.85	0.108	0.079	0.014	0.010	128,488	4.9
	T7 SWCV	2017	2017	30	0.0391	0.2559	0.0028	0.0027	102.01	74.85	0.108	0.079	0.014	0.010	128,488	4.9
	T7 SWCV	2017	2017	40	0.0212	0.1666	0.0024	0.0023	102.01	74.85	0.108	0.079	0.014	0.010	128,488	4.9
	T7 Tractor	2017	2012	40	0.0798	2.2954	0.0064	0.0061	102.01	74.85	0.108	0.079	0.014	0.010	128,488	4.23
	T7 Tractor	2017	2015	40	0.0524	0.5286	0.0038	0.0037	102.01	74.85	0.108	0.079	0.014	0.010	128,488	4.23
Biodiesel (BD20)					g/mile				g of CO2e/MJ		MT CO2e/MMBtu		MT CO2e/gallon		Btu/gallon	mpg
	T7 SWCV	2017	2012	30	0.0415	0.2826	0.0033	0.0032	56.95	59.88	0.060	0.063	0.0076	0.0080	126,700	4.851
	T7 SWCV	2017	2012	40	0.0225	0.1840	0.0029	0.0028	56.95	59.88	0.060	0.063	0.0076	0.0080	126,700	4.851
	T7 SWCV	2017	2015	30	0.0313	0.2559	0.0025	0.0024	56.95	59.88	0.060	0.063	0.0076	0.0080	126,700	4.851
	T7 SWCV	2017	2015	40	0.0170	0.1666	0.0022	0.0021	56.95	59.88	0.060	0.063	0.0076	0.0080	126,700	4.851
	T7 SWCV	2017	2017	30	0.0313	0.2559	0.0025	0.0024	56.95	59.88	0.060	0.063	0.0076	0.0080	126,700	4.851
	T7 SWCV	2017	2017	40	0.0170	0.1666	0.0022	0.0021	56.95	59.88	0.060	0.063	0.0076	0.0080	126,700	4.851
	T7 Tractor	2017	2012	40	0.0638	2.2954	0.0058	0.0055	56.95	59.88	0.060	0.063	0.0076	0.0080	126,700	4.1877
	T7 Tractor	2017	2015	40	0.0419	0.5286	0.0035	0.0033	56.95	59.88	0.060	0.063	0.0076	0.0080	126,700	4.1877
CNG					g/mile				g of CO2e/MJ		MT CO2e/MMBtu		MT CO2e/lb		Btu/lb	miles/lb of CNG
	Urban Bus		2007+		0.0436	0.6500	0.0010	0.0010	78.37	61.75	0.0827	0.0651	0.00167	0.00131	20,160	0.769

For modeling tailpipe GHG emissions, ESA used combustion emission factors in the California-modified Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation (CA-GREET) model, which informs the California Low Carbon Fuel Standard (LCFS). For modeling lifecycle GHG emissions, we used LCFS emission factors based on the CA-GREET model fuel pathways for analyzing the well-to-wheel (WTW) emissions associated with the various transportation fuels. WTW life cycle analysis of a fuel pathway includes the steps from feedstock recovery to finished fuel to actual combustion of the fuel in a motor vehicle. For the example of diesel fuel, WTW includes crude oil recovery, transport, refining of crude in a typical California refinery, transport of finished product (ULSD), and combustion in motor vehicles. For compressed natural gas (CNG), WTW analysis replaces the crude oil recovery, transport and refining steps with natural gas extraction, compression, and transport to a fueling station. For corn-based biofuels, WTW includes crop production, oil extraction and fuel production, and transport to a fueling station. Our analysis uses the CA-GREET lifecycle emission factor for biodiesel feedstock derived from plant oils, consistent with the Edgar and Associates study for GRA.

Table A-3: Emission Factors and Truck Fuel Efficiency
1. For biodiesel trucks, criteria air pollutant emission factors for ROG, NOx, PM-10 and PM-2.5 are derived from EMFAC2014 as a function of calendar year, vehicle model year and speed, and adjusted for 20 percent biodiesel. Percent reduction for BD20 over diesel factors derived from Biodiesel Emissions Fact Sheet available at http://biodiesel.org/what-is-biodiesel/biodiesel-fact-sheets
2. For CNG, criteria air pollutant emission factors are based on factors for zero mile CNG urban buses, from Table 3.2-58 on page 68 of EMFAC2014 Volume III - Technical Documentation available at http://www.arb.ca.gov/msei/downloads/emfac2014/emfac2014-vol3-technical-documentation-052015.pdf
3. CNG emission factor for ROG derived from THC using factors in Table 3.2-59 on page 68 of EMFAC2014 Volume III - Technical Documentation.
4. CNG emission factor for PM10 is conservatively assumed to be equal to CNG PM2.5.
5. Lifecycle CO2e emission factors for all fuels are from the 2015 LCFS Regulation document (diesel factor from Table 6 on page 66, biodiesel and CNG factors from Table 7 on page 83); Available at: http://www.arb.ca.gov/fuels/lcfs/lcfs.htm
6. Diesel tailpipe GHG emissions are from Table 1 on page 12 of CA-GREET 2.0 Supplemental Document and Table of Changes. Available at: http://www.arb.ca.gov/fuels/lcfs/ca-greet/ca-greet.htm
7. Biodiesel (BD20) tailpipe GHG emissions are assumed to be 80 percent of diesel emissions. (20% is biogenic)
8. CNG tailpipe GHG emissions calculated from using Table 2 on page 13 of CA-GREET 2.0 Supplemental Document and Table of Changes (for CO2e) and refuse truck value from Table 9 on page 20 of CA-GREET 2.0 Supplemental Document and Table of Changes (for CH4 and N2O)
9. LHV for diesel, BD20 and CNG from http://www.afdc.energy.gov/fuels/fuel_comparison_chart.pdf
10. Fuel efficiency for T7 SWCV trucks from Table 5 on page 26 of the GREET Model Expansion for WTW Analysis of HD vehicles available at file:///C:/Users/jni/Downloads/GREET%20HDV%20Module%20Expansion.pdf
11. Fuel efficiency for BD20 calculated assuming 99 percent of diesel energy in biodiesel. Source: http://www.afdc.energy.gov/fuels/fuel_comparison_chart.pdf